

# A silicified brachiopod fauna from the Silurian of Iran

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## Contents

Synopsis . . . . .	25
Introduction . . . . .	25
Age and affinities of the fauna . . . . .	25
Ecology . . . . .	27
Systematic Palaeontology . . . . .	27
Order Orthida . . . . .	27
Order Strophomenida . . . . .	31
Order Pentamerida . . . . .	35
Order Rhynchonellida . . . . .	36
Order Spiriferida . . . . .	36
Acknowledgements . . . . .	41
References . . . . .	41

## Synopsis

A silicified brachiopod fauna has been recovered from a single bed in a limestone unit here named the Qarabil Limestone Formation, at the Robat-e-Qarabil inlier in the eastern Elburz Mountains, Iran. Twenty-three different articulate brachiopods are described, including one new genus, *Xerxespirifer* (Family Delthyridae), type species *X. iranicus* sp. nov., and two other new species, *Salopina brandi* and *Pentamerus asiaticus*. A probable Wenlock age is deduced.

## Introduction

The Robat-e-Qarabil inlier lies to the north-east of Iran (Fig. 1), in the eastern Elburz Mountains, and was visited by the 1972 Oxford University Expedition to Iran, who made a geological map of the area, and also made extensive fossil collections, chiefly from the Devonian. The stratigraphy of the inlier has been briefly described by Brice *et al.* (1973 : 179), who described some of the brachiopod faunas, also chiefly from the Devonian; they list a succession, commencing with Horizon 1, 'Marnes calcaires et gréseuses à fragments de Brachiopodes et nombreux gros Poly-piers', here termed the Qarabil Limestone Formation. This formation was measured by the Oxford Expedition as consisting of 52 m of limestones and interbedded marls with corals, which overlie the lavas and tuffs of an unnamed and undated formation beneath. The silicified fauna described in the present paper comes from a single bed 33 m above the base of the Qarabil Formation, 2½ km north-east of Robat-e-Qarabil; the bed is termed 'Lower Group 4' in the unpublished expedition report. Above the Qarabil Limestone Formation there is a stratigraphical break, which is followed by 90 m of thin limestones and marls with occasional sandstones (Horizons 2 and 3 of Brice *et al.* 1973), succeeded by 200 m of quartzites and shales, followed by a 1300 m sequence of clastic and carbonate rocks of largely Devonian age, many of which are richly fossiliferous (but they are not known to be silicified).

## Age and affinities of the fauna

Many of the 23 different articulate brachiopods described below represent genera with a fairly wide age range within the Silurian; some also range down into the Ordovician and others up into

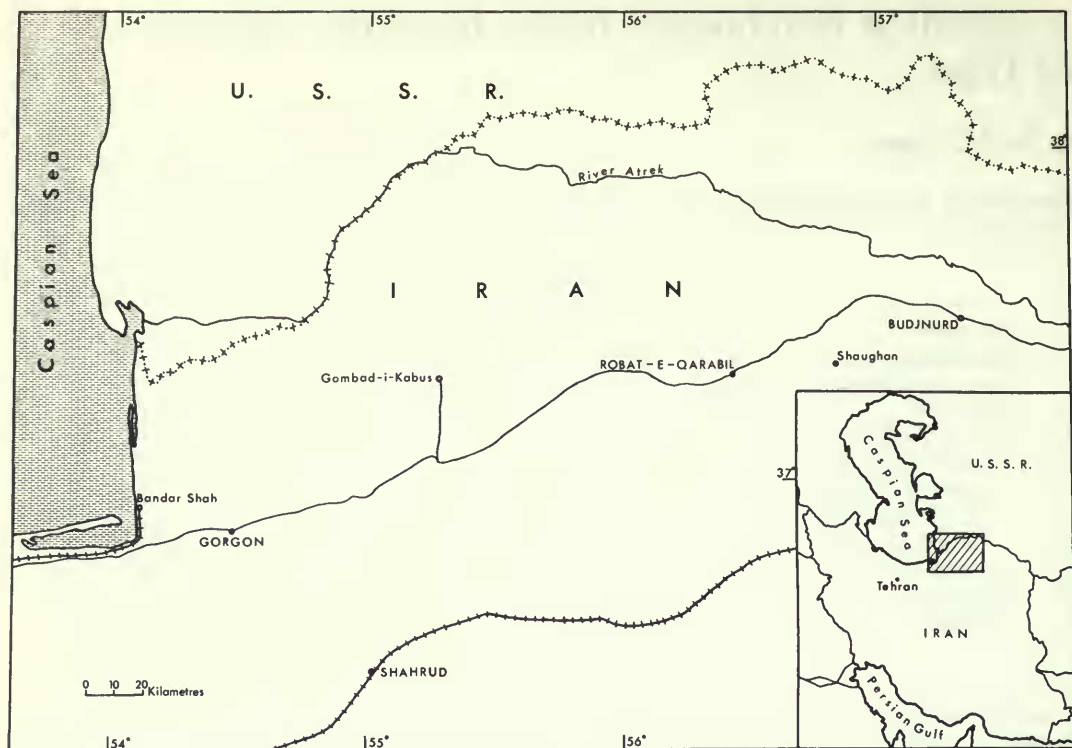


Fig. 1. The geographical position of the Robat-e-Qarabil inlier, Iran.

the Devonian, and there is no doubt that the age of the silicified fauna lies somewhere between the late Llandovery and the early Ludlow. The key forms in the more detailed assessment of age are as follows. *Glyptorthis* is not known from rocks younger than late Wenlock; *Epitomyonia* is not known from rocks younger than middle Wenlock; *Eoplectodonta* is most common in the early Silurian, and is not known from rocks younger than the middle Ludlow; *Shagamella* is not known from rocks earlier than late Wenlock; *Pentamerus* is most common in the Llandovery, and *P. asiaticus* sp. nov. is most like the pre-late Wenlock forms of the genus; *Plicoplasia* is not known from rocks older than the Ludlow; the large numbers of varied spiriferides present suggest an age later rather than earlier in the Silurian. Thus any age assessment would involve an extension of the range of at least some of the genera present, but a Wenlock age seems the most probable for the fauna as a whole, and probably the middle or later part of the Wenlock.

The associated fauna consists of fragments of the trilobite *Diacyclonema*, kindly identified by Dr D. J. Siveter, the bivalve *Palaeoneilo*, kindly identified by Dr N. J. Morris, bryozoans, and the corals listed by Lafuste (in Brice *et al.* 1973 : 181), none of which contradicts the Wenlock age deduced from the brachiopods. No inarticulate brachiopods or graptolites are at present known from the Qarabil Formation.

The affinities of the fauna are puzzling. One of the most common brachiopods, *Xerxespirifer iranicus*, appears to be endemic, which is unusual in the middle Silurian, and the fauna is strikingly different from the roughly contemporary faunas described by Nikiforova (1937), and Sapelnikov & Rukavishnikova (1975) from the nearby southern parts of the Soviet Union. Dürkoop (1970) has partly described a fauna from central Afghanistan, which he ascribes to the Llandovery chiefly on the basis of an unillustrated *Pentamerus*, which may be comparable with the Iranian fauna.

It is not certain upon which continental plate Robat-e-Qarabil lay during Silurian times. In a recent reconstruction Ziegler *et al.* (1977) have extended the tentative boundary of Stöcklin (1974),

which would place Robat-e-Qarabil on the southerly Gondwanan plate. However, this poses problems in that later Devonian and Jurassic faunas found to the north-east of Jarjarm, 50 km to the south-west of Robat-e-Qarabil, have a distinctly European as opposed to a Gondwanan aspect (Dr N. J. Morris, personal communication), which would indicate that the continental suture may have lain to the south, and that Robat-e-Qarabil would have been on the Kazakhstan plate. The question is unresolved, but if the new fauna were eventually found to have come from the Gondwanan plate then it would be of great interest, since no Silurian shelly faunas are known for over 3000 km to the west, or (apart from the possible Afghanistan fauna mentioned above) for a very long way to the east. Perhaps in Silurian times Robat-e-Qarabil lay on a smaller continental unit near the Gondwanan plate, which later drifted northwards.

### Ecology

A total of 53 pairs of articulated valves, 143 disarticulated pedicle valves and 52 disarticulated brachial valves were recovered from the Lower Group 4 sample at Robat-e-Qarabil. However, of all the 23 different brachiopod species represented, only *Plicoplasia* sp. had a great disproportion of one valve to the other (no articulated specimens, 47 pedicle valves and 2 brachial valves), and, as argued below, this species was probably carried into the Lower Group 4 bed from elsewhere. When *Plicoplasia* sp. is therefore discounted, only five brachiopod species are present at over 5% of the total sample: *Salopina brandi* (26%), *Pentamerus asiaticus* (12%), *Lissatrypa* sp. (12%), *Eoplectodonta* aff. *bidecorata* (11%) and *Xerxespirifer iranicus* (10%); these five species together make up 71% of the total brachiopod fauna in the bed. The fauna is, however, a relatively diverse one, and probably indicates deposition under water that was not too shallow, perhaps comparable with the depth range of the *Pentamerus* or *Stricklandia* communities of the Llandovery of the Welsh Borderland (Ziegler, Cocks & Bambach 1968). This deduction is supported by the abundance of the associated coral fauna in Lower Group 4, since corals also reach their ecological acme in the *Pentamerus* and *Stricklandia* community depths. The relative abundance of spiriferides in the fauna also suggests a mid-shelf ecological position by comparison with the common mid-shelf spiriferide faunas of the later Silurian and the Upper Palaeozoic.

### Systematic palaeontology

References to the authors of genera and species are given below in the list of references (p. 41), but those to the authors of higher taxa will be found in the *Treatise on Invertebrate Paleontology* (Williams *et al.* 1965).

Order **ORTHIDA** Schuchert & Cooper, 1932

Superfamily **ORTHACEA** Woodward, 1852

Family **HESPERORTHIDAE** Schuchert & Cooper, 1931

Subfamily **HESPERORTHINAE** Schuchert & Cooper, 1931

Genus **HESPERORTHIS** Schuchert & Cooper, 1931

*Hesperorthis* ? sp.

(Figs 4, 5)

**MATERIAL.** Two pedicle valves, BB 93340 (Fig. 5) and BB 93338, and two brachial valves, BB 93336 (Fig. 4) and BB 93339.

**DIMENSIONS** (in mm).

	length	width
BB 93340, pedicle valve	18.8	c. 23
BB 93339, brachial valve	13.4	17.3

**REMARKS.** Although the pedicle valves are poorly preserved, they contain a suggestion of an apical plate in the delthyrium which indicates their attribution to *Hesperorthis*, in contrast to the open delthyrium of *Dolerorthis*. Chiang (1972) suggested that *Hesperorthis* should be confined to forms like the type species *H. tricenaria*, which possess only simple costae, as opposed to those

like the Iranian form, whose costellae branch at mid-shell length (Fig. 5). These species with branched costellae, such as *H. gotlandica* and *H. martinssoni* from the upper Silurian of Gotland (Bassett & Cocks 1974 : pl. 1), have long been classified within *Hesperorthis*, but the differences observed by Chiang appear to be consistent from species to species, and hence this record of *Hesperorthis* is qualified by a query.

Subfamily **DOLERORTHINAE** Öpik, 1934

Genus **DOLERORTHIS** Schuchert & Cooper, 1931

*Dolerorthis* sp.

(Figs 2, 3)

**MATERIAL.** One pair of conjoined valves, BB 93341 (Fig. 2), and two pedicle valves, BB 93337 (Fig. 3) and BB 93349.

DIMENSIONS (in mm).	length	width	thickness
BB 93341, conjoined valves	17.2	19.8	6.4
BB 93349, pedicle valve	18.4	c. 22	—

**REMARKS.** Unfortunately the interior cannot be seen on any of the three specimens available, but the shape, ribbing, and open delthyrium and notothyrium are all typical of *Dolerorthis*, a genus which is well known and relatively common in rocks of Caradoc to early Devonian ages.

Subfamily **GLYPTORTHINAE** Schuchert & Cooper, 1931

Genus **GLYPTORTHIS** Foerste, 1914

*Glyptorthis* sp.

**MATERIAL.** Two small pairs of conjoined valves, BB 93391–92, two pedicle valves, BB 93348 and on BB 93405, and three brachial valves, BB 93345–7.

DIMENSIONS (in mm).	length	width	thickness
BB 93391, conjoined valves	4.2	6.0	2.3
BB 93348, pedicle valve	5.5	7.8	—
BB 93346, brachial valve	10.1	c. 12	—

**REMARKS.** *Glyptorthis* is rare in rocks of Silurian age, although *G. whitei* has been described by Bassett (1972) from the late Wenlock of Wales. The Iranian form differs from *G. whitei* in having relatively larger frilly growth lamellae which are also spaced further apart. In the pedicle valve interior the Welsh form has a raised muscle platform absent from the single Iranian pedicle interior.

Family **SCENIDIIDAE** Kozłowski, 1929

Genus **SKENIDIODES** Schuchert & Cooper, 1931

*Skenidioides* sp.

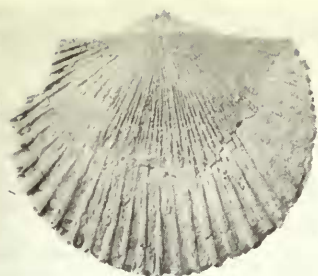
(Fig. 14)

**MATERIAL.** Three silicified pedicle valves, BB 93390 (Fig. 4), BB 93356–57.

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**Figs 2–11.** Orthida from the Qarabil Limestone. (2, 3) *Dolerorthis* sp.; (2) BB 93341, conjoined valves viewed dorsally, laterally and ventrally,  $\times 2$ ; (3) BB 93337, pedicle valve,  $\times 3$ . (4, 5) *Hesperorthis* ? sp.; (4) BB 93336, brachial valve interior,  $\times 2$ ; (5) BB 93340, pedicle valve exterior,  $\times 1.5$ . (6–11) *Salopina brandi* sp. nov.; (6) BB 93333, **holotype**, conjoined valves viewed dorsally, laterally and ventrally,  $\times 4$ ; (7) BB 93334, a fragmentary brachial valve viewed externally and internally,  $\times 4$ ; (8) BB 93330, juvenile conjoined valves viewed dorsally and ventrally,  $\times 4$ ; (9) BB 93331, pedicle valve viewed externally and internally,  $\times 4$ ; (10) BB 93332, interior of a fragmentary pedicle valve,  $\times 5$ ; (11) BB 93335, brachial valve exterior,  $\times 2$ .

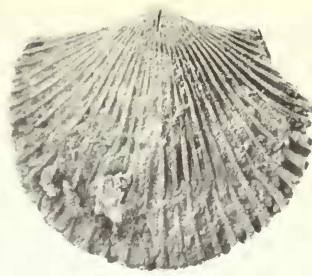




2a



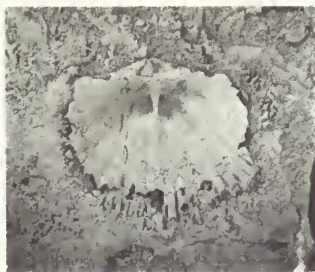
2b



2c



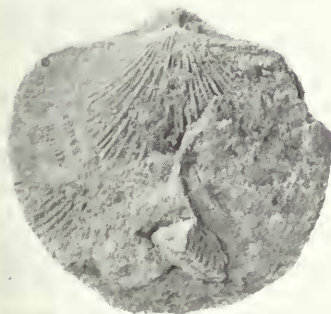
3



4



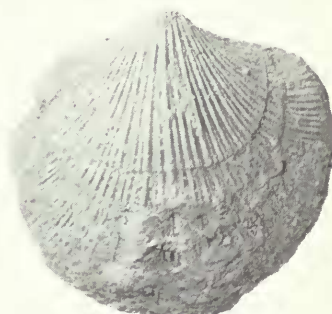
5



6a



6b



6c



7a



7b



8a



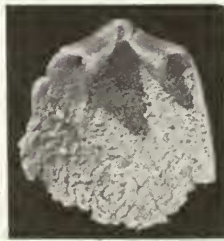
8b



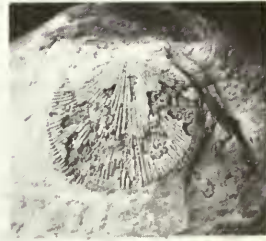
9a



9b



10



11

**DIMENSIONS.** All three valves have broken edges, but they are estimated to have been approximately 5 mm long and 6 mm wide when complete.

**REMARKS.** There are many described species of *Skenidioides* from the Ordovician and Silurian (ten from Britain alone, Cocks 1978), and these fragmentary pedicle valves are best left under open nomenclature.

Superfamily **ENTELETACEA** Waagen, 1884

Family **SCHIZOPHORIIDAE** Schuchert, 1929

Subfamily **DRABOVIINAE** Havlíček, 1950

Genus ***SALOPINA*** Boucot, 1960

*Salopina brandi* sp. nov.

(Figs 6–11)

**DIAGNOSIS.** Ventribiconvex *Salopina* with subcircular outline, weak dorsal sulcus, fine costellae and short, divergent brachiophores.

**DESCRIPTION.** *Exterior.* Ventribiconvex with subcircular outline. Weak sulcus on brachial valve. Hinge line relatively wider in juvenile individuals (Fig. 8). Small open delthyrium. Small curved apsacine pedicle interarea under incurved umbo, brachial valve interarea very small, with umbo scarcely developed. Ornament of fine costellae, hollow in cross-section. Prominent growth lines at irregular intervals.

*Pedicle valve interior.* Strong pair of teeth, supported by dental lamellae which merge with the valve floor posterior to the anterior end of the teeth. Muscle field weakly impressed and indistinct. Valve interior smooth, except at the periphery where the external costellae can be seen.

*Brachial valve interior.* Small, slender linear cardinal process. Strong brachiophores which also act as the anterior part of the socket. However, the brachiophores are relatively short for the genus and diverge from each other at approximately 90°. Muscle field of two pairs of adductor scars, separated centrally by a wide and shallow median ridge; the anterior pair larger than the posterior pair (Fig. 7b).

**MATERIAL.** Holotype BB 93333, conjoined valves (Fig. 6). Additional material: 7 other conjoined valves, including BB 93330 (Fig. 8) and BB 93353; 31 pedicle valves, including BB 93331–2 (Figs 9, 10), some fragmentary; 18 brachial valves, including BB 93334–5 (Figs 7, 11), some fragmentary, all from Lower Group 4, Robat-e-Qarabil inlier, Iran.

DIMENSIONS (in mm).	length	width	thickness
BB 93333, conjoined valves (holotype)	9.9	10.3	5.9
BB 93330, conjoined valves	4.1	7.1	2.8
BB 93353, conjoined valves	5.8	7.4	3.4

**REMARKS.** Walmsley *et al.* (1969) have given a useful review of the ten species which they ascribe to *Salopina* which had been described up to that time. From their table of specific differences, it can be seen that *Salopina brandi* falls into the group with relatively fine costellae, and it can be distinguished from other species with fine or medium costellae as follows. From *S. lunata* (J. de C. Sowerby, 1839), from the Ludlow of Britain, it differs in the shorter pedicle valve muscle field and the short divergent brachiophores; from *S. submedia* (McLearn, 1924), from the Telychian to Pridoli of North America, it differs in its convex brachial valve and shorter pedicle valve muscle field; from *S. conservatrix* (McLearn, 1924), from the Telychian to Eltonian of eastern North America and Europe, it differs in the valve outline, and also in the short divergent brachiophores, as opposed to the thin, erect to slightly convergent brachiophores of *S. conservatrix*; from *S. shelvensis* Walmsley, Boucott & Harper, 1969, from the Idwian of the Welsh Borderland, in the development of a dorsal sulcus, and once again in the distinctive brachiophores, which in *S. shelvensis* are thin and almost parallel. The subsequently-described (Johnson *et al.* 1976) species *S. delta* differs from *S. brandi* in possessing coarser costellae, a relatively wider hinge line, longer dental lamellae, and distinctive supporting plates to the brachiophore in the brachial valve.

Family **DICAELOSIIDAE** Cloud, 1948Genus **DICOELOSIA** King, 1850*Dicoelosia* sp.

(Fig. 12)

**MATERIAL.** One pair of conjoined valves, BB 93342 (Fig. 12), length 4.8 mm, width 4.6 mm, thickness 2.4 mm.

**REMARKS.** The single specimen of *Dicoelosia* found in Lower Group 4 at Robat-e-Qarabil is relatively long, and similar in this respect to *D. verneuiliana* (Beecher) from the Telychian and Sheinwoodian of Gotland, Sweden (Wright 1968) and *D. alticavata* (Whittard & Barker) from the Telychian of Britain. It is also very indented at the anterior margin, which distinguishes it from *D. biloba* (Linnaeus), *D. paralata* Bassett, *D. osloensis* Wright, *D. oklahomensis* Amsden and from other species outside the Silurian. It is also relatively longer than *D. parvifrons* Johnson, Boucot & Murphy, and with its very concave brachial valve probably represents an undescribed species.

Genus **EPITOMYONIA** Wright, 1968*Epitomyonia* aff. *clausula* Johnson, Boucot & Murphy, 1976

(Fig. 13)

**MATERIAL.** Three pairs of conjoined valves, BB 93344 (Fig. 13), BB 93345 and BB 93354, and one pedicle valve BB 93355.

DIMENSIONS (in mm).	length	width	thickness
BB 93344, conjoined valves	3.4	3.9	1.9
BB 93345, conjoined valves	3.5	4.3	1.9
BB 93354, conjoined valves	2.6	3.5	1.4

**REMARKS.** *Epitomyonia* was originally described from the Ashgill of Europe (Wright 1968), and is still not recorded from rocks of Llandovery age. However, it is now known by the species *E. clausula* from the Roberts Mountain Formation (Wenlock) of Nevada, U.S.A. (Johnson *et al.* 1976), and that species appears very similar to the scarce material from Iran, although the specific determination cannot be confirmed until internal details of the Iranian form are available.

Order **STROPHOMENIDA** Öpik, 1934Superfamily **PLECTAMBONITACEA** Jones, 1928Family **SOWERBYELLIDAE** Jones, 1928Genus **EOPLECTODONTA** Kozłowski, 1929*Eoplectodonta* aff. *bidecorata* (Barrande, 1879)

(Figs 16, 17)

**MATERIAL.** Three pairs of conjoined valves BB 93360, BB 93362, BB 93364; 13 pedicle valves, including BB 93361 (Fig. 17), BB 93363, BB 93365, BB 93367–8; and 13 brachial valves, including BB 93366 (Fig. 16), BB 93359, BB 93369–70.

DIMENSIONS (in mm).	length	width
BB 93360, conjoined valves	10.4	c. 15.2
BB 93361, pedicle valve	5.6	10.3
BB 93362, pedicle valve	7.6	c. 15.5
BB 93366, brachial valve	6.9	12.5

**REMARKS.** Cocks (1970 : 168) listed the late Silurian species of *Eoplectodonta*, which consist of *E. duvalii* (Davidson) from the Wenlock and Eltonian of Britain and Gotland, *E. sowerbyana* (Barrande) and *E. bidecorata* (Barrande), both from the Wenlock of Czechoslovakia, and possibly '*Sowerbyella*' *minuta* Kulkov from the late Wenlock of the Altai Highlands, Soviet Union.



'*S.*' *minuta* is poorly known, but differs from the Iranian form in its very wide spaces between the primary costae. *E. duvalii*, *E. sowerbyana*, *E. bidecorata* and the Iranian form are all very similar and clearly closely related to each other, except that *E. sowerbyana* has notably fewer costae than the rest (Havlíček 1967: 60), and in fact the Iranian form is most similar to *E. bidecorata* in this respect, hence its tentative attribution. However, the Iranian form differs from *bidecorata* in at least two minor points, firstly in the common occurrence of low but prominent anterior plicae, which Havlíček describes as rare in *bidecorata*, and secondly by the development of a small but persistent median septum in the brachial valve (Fig. 16), consisting of scarcely more than a conjoined row of prominent tubercles. This septum has not been described or illustrated for *E. sowerbyana* or *E. bidecorata* by Havlíček (1967), but can be seen in the additional material of *sowerbyana* illustrated by Cocks (1970: pl. 13, figs 5, 8) and also in the material of *E. duvalii* illustrated by Bassett (1974: pl. 22, fig. 5), and perhaps occurred sporadically in all late Silurian populations of *Eoplectodonta*. However, its occurrence seems more prevalent in the Iranian form.

Superfamily STROPHOMENACEA King, 1846

Family STROPHOMENIDAE King, 1846

Subfamily STROPHOMENINAE King, 1846

Genus *KATASTROPHOMENA* Cocks, 1968

*Katastrophomena* sp.

MATERIAL. One pedicle valve, BB 93376, length 14 mm approx., width 19 mm approx., and one brachial valve, BB 93377, length 11.1 mm, width 17.8 mm.

REMARKS. The interior of neither specimen is visible, but the shape and ornament of these valves are typical of *Katastrophomena*, which is known from the Ashgill to the early Ludlow of Europe and North America.

Subfamily LEPTAENINAE Hall & Clarke, 1893

Genus *LEPTAENA* Dalman, 1828

*Leptaena* sp.

(Fig. 15)

MATERIAL. Two pedicle valves, BB 93371 (Fig. 15) and BB 93372.

DIMENSIONS (in mm).	length of disc	length of trail	width
BB 93371, pedicle valve	8.3	7.3	c. 14
BB 93372, pedicle valve	7.5	4.1	c. 12

REMARKS. This relatively small species of *Leptaena* is represented in the Iranian collection from Lower Group 4 by pedicle valves only. It is generally similar to a number of previously-described species, such as *L. ziegleri* and *L. purpurea* from the late Llandovery of the Welsh Borderland (Cocks 1968), but the outline of the disc and valve of the Iranian specimens is more rounded than the rather squarer or more quadrilateral outline of the British forms.

**Figs 12–21.** Orthida and Strophomenida from the Qarabil Limestone. (12) *Dicoelosia* sp., BB 93342, conjoined valves, viewed ventrally, dorsally and laterally,  $\times 5$ . (13) *Epitomyonia* aff. *clausula*, BB 93344, conjoined valves viewed laterally and dorsally,  $\times 5$ . (14) *Skenidioides* sp., BB 93390, pedicle valve interior,  $\times 6$ . (15) *Leptaena* sp., BB 93371, pedicle valve exterior, interior, and viewed laterally,  $\times 3$ . (16, 17) *Eoplectodonta* aff. *bidecorata*; (16) BB 93366, brachial valve interior,  $\times 4$ ; (17) BB 93361, pedicle valve exterior,  $\times 4.5$ . (18) *Shagamella* ? sp., BB 93373, pedicle valve interior,  $\times 5$ . (19) Chilidiopsid gen. et sp. nov., BB 93385, brachial valve interior and exterior,  $\times 4$ . (20) *Coolinia* cf. *pecten*, BB 93383, brachial valve interior and exterior,  $\times 9$ . (21) *Brachyprion* sp., BB 93378, pedicle valve interior,  $\times 2$ .





12a



12b



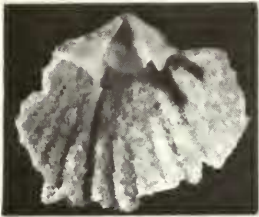
12c



13a



13b



14



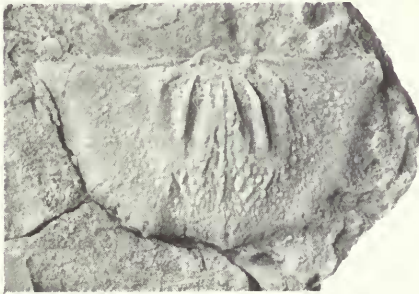
15a



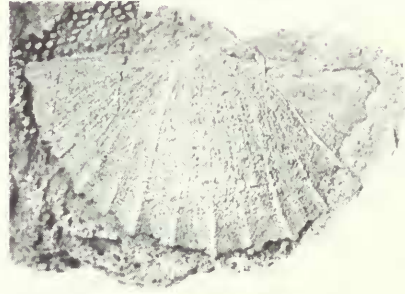
15b



15c



16



17



18



19a



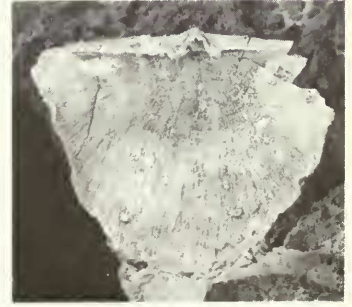
19b



20a



20b



21

Family **STROPHEODONTIDAE** Caster, 1939Genus **BRACHYPRION** Shaler, 1865*Brachyprion* sp.

(Fig. 21)

MATERIAL. Two pedicle valves, BB 93378 (Fig. 21) and BB 93379.

DIMENSIONS (in mm).	length	width	height
BB 93378, pedicle valve	16.4	c. 22	c. 5
BB 93379, pedicle valve	14.1	c. 19	c. 5

REMARKS. The degree of convexity is not properly conveyed by the photograph (Fig. 21). This species of *Brachyprion* is very comparable with *B. arenaceus* from the late Llandovery of the Welsh Borderland (Cocks 1967).

Genus **LEPTOSTROPHIA** Hall & Clarke, 1892*Leptostrophia* sp.

MATERIAL. Four pedicle valves, BB 93380–2 and on BB 93372.

DIMENSIONS (in mm).	length	width
BB 93380, pedicle valve	c. 10	c. 12
BB 93381, pedicle valve	3.9	c. 6

REMARKS. It is uncertain whether these four rather poorly preserved pedicle valves represent a small species of *Leptostrophia*, or whether they are juveniles. Their interiors show muscle fields typical of *Leptostrophia*, with muscle-bounding ridges diverging at approximately 70°. The ribbing style appears to be multicostellate, rather than the unequal parvicostellae more common in Silurian species of *Leptostrophia* (Cocks 1967).

Superfamily **DAVIDSONIACEA** King, 1850Family **CHILIDIOPSIDAE** Boucot, 1959Genus **COOLINIA** Bancroft, 1949*Coolinia* cf. *pecten* (Linnaeus, 1758)

(Fig. 20)

MATERIAL. One brachial valve, BB 93383 (Fig. 20), and two pedicle valves, BB 93384 and on BB 93372.

REMARKS. All three specimens are fragmentary, not extending to the anterior or lateral margins, and the largest is preserved to a length of only 6 mm (large specimens of *Coolinia* from Europe reach lengths of over 40 mm). However, these small shells seem similar to the widespread *C. pecten*, which occurs abundantly in the Silurian of Sweden, Norway, Britain and Czechoslovakia.

**Chilidiopsis** gen. et sp. nov.

(Fig. 19)

MATERIAL. Two brachial valves, BB 93385 (Fig. 19) and BB 93386, and a fragment of pedicle valve, BB 93387.

DIMENSIONS (in mm).	length	width
BB 93385, brachial valve	5.2	7.1
BB 93386, brachial valve	5.1	c. 8

REMARKS. This species differs from other related and contemporary chilidiopsids, such as species of *Coolinia*, *Fardenia* and *Morinorhynchus*, in possessing an ornament of differentiated parvicostellae, not unlike the stropheodontid *Leptostrophia*. The only other Silurian chilidiopsid with such an ornament is *Valdaria*, but in that genus the costellae swing round to merge with the hinge-line laterally (Bassett & Cocks 1974: pl. 5), and the socket ridges are poorly developed in contrast

with the prominent very divergent socket plates of the Iranian form. The Robat-e-Qarabil brachial valves are very gently convex, and the single fragment of pedicle valve (which lacks the umbonal region) is rather more convex; it is not known whether the species is naturally small for the family, or whether the rare material is of juveniles. Unfortunately the small number of specimens to hand is inadequate to erect new generic and specific names.

Superfamily **CHONETACEA** Bronn, 1862

Family **ANOPLIIDAE** Muir-Wood, 1962

Genus **SHAGAMELLA** Boucot & Harper, 1968

*Shagamella* ? sp.

(Fig. 18)

**MATERIAL.** One pedicle valve, BB 93373 (Fig. 18).

**DIMENSIONS.** Length 3.5 mm, width 4.9 mm, height 1.9 mm.

**REMARKS.** The shape and form of this single valve recall *Shagamella*, which is known from the late Silurian of Britain and Venezuela (Boucot & Harper 1968). However, no spines can be seen on the valve edge, which is imperfectly preserved. A form approaching this is also seen in the contemporary plectambonitacean *Leangella*, but the distinctive muscle platform of the latter is not preserved on the Iranian specimen; hence the attribution to the anoplid.

Order **PENTAMERIDA** Schuchert & Cooper, 1931

Superfamily **PENTAMERACEA** M'Coy, 1844

Family **PENTAMERIDAE** M'Coy, 1844

Subfamily **PENTAMERINAE** M'Coy, 1844

Genus **PENTAMERUS** J. Sowerby, 1813

*Pentamerus asiaticus* sp. nov.

(Figs 22–26)

**DIAGNOSIS.** Very weakly trilobate *Pentamerus*, with relatively small and tightly incurved beak, and with relatively wide apical angles.

**DESCRIPTION.** Biconvex with weak trilobation, apical angle wide for the genus, approximately 90° for the pedicle valve and 110° for brachial valve. Pedicle umbo small and incurved (Fig. 22c), brachial umbo also small with orthocline interarea. Ornament absent, apart from growth lines. Pedicle valve interior has a simple spondylium and supporting septum (Fig. 24), extending to about valve mid-length. A deltidial plate is preserved. The brachial valve interior has discrete outer plates (Fig. 25), extending to just under valve mid-length in adult specimens.

**MATERIAL.** Holotype BB 93388, conjoined valves (Fig. 22). Additional material, one other pair of conjoined valves, BB 93396 (Fig. 26), 5 brachial valves, BB 93397–401, including BB 93399 (Fig. 25), and 16 pedicle valves, BB 93402 (Fig. 23), BB 93403 (Fig. 24) and BB 93404–17.

**DIMENSIONS** (in mm).

	length	width	thickness
BB 93388, holotype, conjoined valves	47.3	48.2	22.1
BB 93397, brachial valve	—	61.4	21.5
BB 93404, pedicle valve	33.2	c. 37	18.0

**REMARKS.** The diagnosis separates *P. asiaticus* from the common Llandovery species *P. oblongus*, which is more trilobate; from the Wenlock *P. esthonus* (revised by Bassett 1977), which has a larger pedicle umbo and a relatively smaller cardinal margin; from *P. scalaris*, *P. subquadratus* and *P. issensis*, all from the Wenlock of the Urals (Sapelnikov 1972), by the small, tightly incurved umbo; from *P. longiseptatus* from the Llandovery of Kazakhstan and *P. oblongiformis* from the Ludlow of Kazakhstan, which both have a larger beak and narrower apical angle (Nikiforova



1937, Sapelnikov & Rukavishnikova 1975); from *P. magianicus* from the Lower Silurian of the Gornoi Altai (Menakova 1964) and Tian-Shan, which has several lobations and a narrower apical angle. There are also several nominal species of *Pentamerus* from North America, but these are either generically unrevised, junior synonyms of *P. oblongus*, or otherwise dissimilar to *P. asiaticus*.

Subfamily **CLORINDINAE** Rzonisnitskaya, 1956

Genus **CLORINDA** Barrande, 1879

*Clorinda* ? sp.

(Fig. 27)

**MATERIAL.** Two pedicle valves, BB 93418 (Fig. 27) and BB 93419.

DIMENSIONS (in mm).	length	width	thickness
BB 93418, pedicle valve	12.1	c. 14	5.0
BB 93419, pedicle valve	c. 15	c. 18	4.7

**REMARKS.** Since no brachial valves are available, the generic attribution must remain uncertain, but the form and structure of these two pedicle valves are consistent with *Clorinda* or *Brevilamula*.

Order **RHYNCHONELLIDA** Kuhn, 1949

Superfamily **RHYNCHONELLACEA** Gray, 1848

Family **TRIGONIRHYNCHIIDAE** Maclaren, 1965

Genus **ROSTRICELLULA** Ulrich & Cooper, 1942

*Rostricellula* sp.

**MATERIAL.** Seven articulated specimens, BB 93420–6, one other pedicle valve, BB 93427, and one other brachial valve, BB 93428.

DIMENSIONS (in mm).	length	width	thickness
BB 93420, conjoined valves	4.6	4.8	1.9
BB 93421, conjoined valves	3.3	5.4	3.2

**REMARKS.** These small sulcate rhynchonellaceans lack a cardinal process, precluding their inclusion in the two most common Silurian genera, *Stegerhynchus* and *Ferganella*. They are attributed here to *Rostricellula*, which lacks a cardinal process. It is not known whether these small specimens represent a small species, or whether they are juveniles.

Order **SPIRIFERIDA** Waagen, 1883

Superfamily **ATRYPACEA** Gill, 1871

Family **ATRYPIDAE** Gill, 1871

Genus **ATRYPA** Dalman, 1828

*Atrypa* ? sp.

**MATERIAL.** Two pedicle valves, BB 93429, length 12.8 mm, width 14.4 mm, and BB 93430.

**Figs 22–31.** Pentamerida and Spiriferida from the Qarabil Limestone. (22–26) *Pentamerus asiaticus* sp. nov.; (22) BB 93388, **holotype**, conjoined valves viewed ventrally, dorsally and laterally,  $\times 1$ ; (23) BB 93402, pedicle valve viewed dorsally,  $\times 1$ ; (24) BB 93403, silicified pedicle valve showing the internal structures,  $\times 2$ ; (25) BB 93399, silicified brachial valve interior,  $\times 5$ ; (26) BB 93396, conjoined valves viewed ventrally and dorsally,  $\times 2$ . (27) *Clorinda* sp., BB 93418, pedicle valve exterior,  $\times 2$ . (28–31) *Lissatrypa* sp.; (28) BB 93431, conjoined valves viewed ventrally, dorsally, laterally and anteriorly,  $\times 3$ ; (29) BB 93447, pedicle valve interior,  $\times 3$ ; (30) BB 93432, broken conjoined valves viewed from the posterior showing spiralia,  $\times 3$ ; (31) BB 93443, broken conjoined valves viewed dorsally and laterally, showing spiralia and brachiophores,  $\times 3$ .



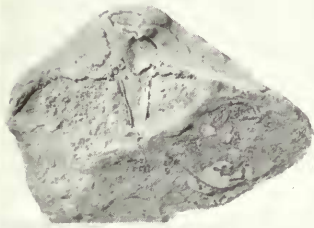
22a



22b



22c



23



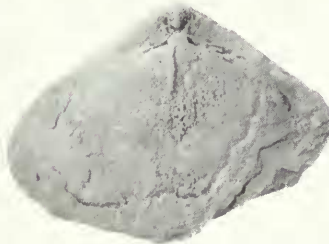
24



25



26a



26b



27



28a



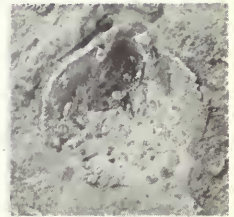
28b



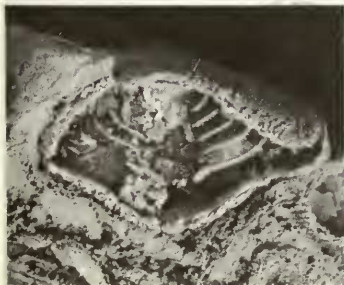
28c



28d



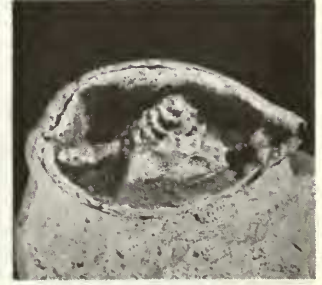
29



30



31a



31b

REMARKS. Although certainly atrypid, the material is not sufficient for a positive generic attribution especially since the interiors are obscured by matrix. The growth lines are pronounced, even verging on frilly, over some of the costae.

Family **LISSATRYPIDAE** Twenhofel, 1914

Genus **LISSATRYPA** Twenhofel, 1914

*Lissatrypa* sp.

(Figs 28–31)

MATERIAL. Sixteen articulated individuals, BB 93431 (Fig. 28), BB 93432 (Fig. 30), BB 93433 (Fig. 31) and BB 93434–46, and one pedicle valve, BB 93447 (Fig. 29).

DIMENSIONS (in mm).	length	width	thickness
BB 93431, conjoined valves	9.8	9.3	6.3
BB 93439, conjoined valves	13.2	14.7	7.9

REMARKS. The internal structures have been delicately silicified in several of the specimens (Figs 30, 31), and the characteristic spiralia and brachiophores of *Lissatrypa* are clearly visible as set out in Copper (1973). Dr P. Copper has also seen the specimens and kindly confirmed the identification. However, only the two measured specimens are completely clear of matrix, and although the shape and form of BB 93439 is similar to *Lissatrypa atheroidea*, the type species from Anticosti Island, Canada (Twenhofel 1914: pl. 1), the smaller specimen (Fig. 28) is proportionately thicker and less sulcate, which precludes specific identification of the Iranian form at present. *Lissatrypa* ? *sulcata* from Gotland differs in possessing a distinctive narrow median depression in both valves (Bassett & Cocks 1974: pl. 9).

Superfamily **SPIRIFERACEA** King, 1846

Family **CYRTIIDAE** Fredericks, 1919

Genus **EOSPIRIFER** Schuchert, 1913

*Eospirifer* sp.

(Figs 32–33)

MATERIAL. Two pedicle valves, BB 93448 (Fig. 32) and BB 93449, and three brachial valves, BB 93450 (Fig. 33) and BB 93451–52.

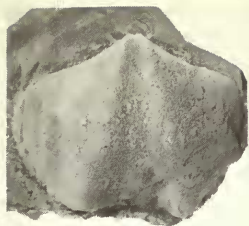
DIMENSIONS (in mm).	length	width	thickness
BB 93448, pedicle valve	24.7	29.9	9.9
BB 93451, brachial valve	21.1	30.7	8.7

REMARKS. These finely-ribbed *Eospirifer* specimens have a more pronounced sulcus than the type species, *E. radiatus*, which is known from the late Llandovery to the Ludlow of Europe, North America and Asia. There is no hint of lateral ribbing on any of the material available.

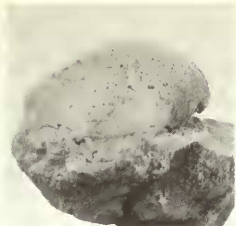
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Figs 32–41. Spiriferida from the Qarabil Limestone. (32, 33) *Eospirifer* sp.; (32) BB 93448, pedicle valve viewed ventrally and laterally,  $\times 1$ ; (33) BB 93450, broken brachial valve showing the exterior and the interior,  $\times 3$ . (34–39) *Xerxespirifer iranicus* gen. et sp. nov.; (34) BB 93453, holotype, conjoined valves viewed dorsally, laterally and ventrally,  $\times 3$ ; (35) BB 93454, conjoined valves,  $\times 3$  – (35a) exterior viewed obliquely from anteroventrally, and (35b) interior with pedicle valve below, showing the distinctive muscle field, and a fragment of the brachial valve above; (36) BB 93464, pedicle valve exterior,  $\times 2$ ; (37) BB 93463, brachial valve exterior,  $\times 2$ ; (38) BB 93455, internal view of conjoined valves with brachial valve below and fragment of pedicle valve above,  $\times 3$ ; (39) BB 93462, brachial valve interior, with a small fragment of the pedicle valve attached to the posterior left of the hinge line,  $\times 4.5$ . (40, 41) *Plicoplasia* sp.; (40) BB 93469 exterior, interior and lateral views of pedicle valve,  $\times 5$ ; (41) BB 93470, interior view of pedicle valve,  $\times 4.5$ .





32a



32b



33a



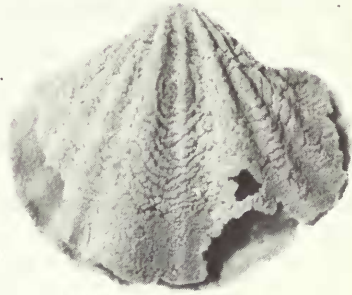
33b



34a



34b



34c



35a



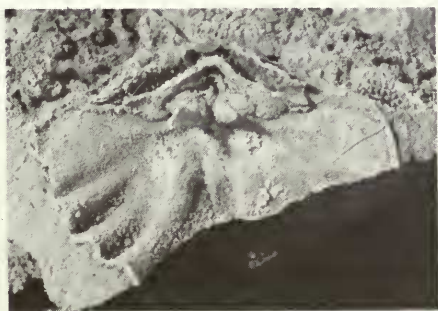
35b



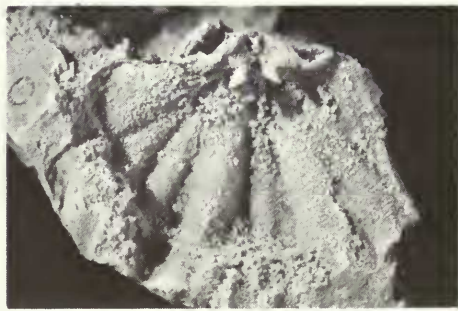
36



37



38



39



40a



40b



40c



41

## Family AMBOCOELIIDAE George, 1931

Genus *PLICOPLASIA* Boucot, 1959*Plicoplasia* sp.

(Figs 40–41)

MATERIAL. Forty-seven pedicle valves, including BB 93469 (Fig. 40), BB 93470 (Fig. 41) and BB 93471–98, many fragmentary, and two fragmentary brachial valves, BB 93499–500.

DIMENSIONS (in mm).	length	width	thickness
BB 93472, pedicle valve	6.5	7.4	3.3
BB 93475, pedicle valve	6.3	7.7	3.4

REMARKS. This chiefly Devonian genus has only recently been described from beds of Silurian age (Johnson *et al.* 1976 : 94), namely from the Ludlow of Nevada, U.S.A., the Wenlock of Arctic Canada and the Ludlow of Australia. The great numerical disproportion of pedicle over brachial valves in the Iranian sample suggests that these shells have been current-sorted and swept into the area of deposition from elsewhere; this is supported by the fact that nearly all the shells are broken anteriorly and laterally, where the valves are weaker.

## Family DELTHYRIDAE Waagen, 1883

## Subfamily ACROSPIRIFERINAE Termier &amp; Termier, 1949

Genus *XERXESPIRIFER* nov.

TYPE SPECIES. *Xerxespirifer iranicus* sp. nov. (see below).

DIAGNOSIS. Delthyrid like *Howellella* but with pinched-in pedicle muscle field, and with a median rib in the sulcus of the pedicle valve and a corresponding hollow in the brachial valve fold.

REMARKS. In its characteristic median rib *Xerxespirifer* differs from *Howellella* in the same way as the kozlowskielline *Holcospirifer* differs from its relative *Boucotinskia*, and also as the eospiriferid *Nikiforovaena* differs from *Striispirifer* (for discussion see Bassett *et al.* 1976 : 620). The narrow width of the muscle field in the new genus is also a point of distinction from *Howellella*, as is also the more incurved beak. The presence of a small cardinal process is unusual in the Spiriferida.

*Xerxespirifer iranicus* sp. nov.

(Figs 34–39)

DESCRIPTION. *Exterior*. Ventribiconvex, with valves elliptical in outline, maximum width anterior to hinge line. Pedicle valve beak incurved, with interarea small, curved and apsacline, small open delthyrium, housing a presumably functional pedicle posteriorly. Brachial valve with very small interarea and almost imperceptible umbo. Radial ornament plicate, with ribs rounded in cross-section, with from three to six ribs on each flank; a small but distinctive median rib on the pedicle valve sulcus and a complementary trough on the fold in the brachial valve. Concentric ornament of fine growth lines.

*Pedicle valve interior*. Teeth small, but curved dorsoposteriorly (Fig. 35b), supported by small dental plates posteriorly only. There is no median septum. Muscle field well-impressed and pear-shaped, but narrow for the family, and extending less than half the valve length (Fig. 35b).

*Brachial valve interior*. Cardinal process small but distinct (Fig. 39). Sockets rounded, bounded anteriorly by curved socket plates which coalesce laterally with the hinge line. There is no median septum. Brachiophore bases short and stubby, protruding ventrolaterally at about 80° to each other just anterior to the cardinal process, but separated from each other by a small cavity. The form of the spiralia is unknown. Adductor muscle scars obscure, but perhaps represented by a pair of suboval areas at about valve mid-length (seen broken off in Fig. 38).



**MATERIAL.** Ten conjoined valves, including holotype BB 93453 (Fig. 34), BB 93454 (Fig. 35), BB 93455 (Fig. 38), BB 93456–61 and BB 93462 (Fig. 39), one other brachial valve, BB 93463 (Fig. 37), and 5 other pedicle valves, BB 93464 (Fig. 36) and BB 93465–8.

DIMENSIONS (in mm).	length	width	thickness
BB 93453, conjoined valves, holotype	9.3	11.1	7.6
BB 93456, conjoined valves	13.2	16.1	10.8
BB 93459, conjoined valves	c. 12	13.7	c. 9

**REMARKS.** The Iranian material described here as *X. iranicus* is the only material so far known which can be ascribed to *Xerxespirifer*. Whether or not the new genus is truly endemic to Iran is not yet known. *X. iranicus* is almost certainly the same form as that identified as *Platystrophia* sp. by Brice *et al.* (1973 : 183; pl. 21, fig. 13), but whose internal structures were then unknown.

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